Research and Development Technical Report

ECOM-4482

# EXPERIMENTAL INVESTIGATION OF VERY HIGH FREQUENCY SLOT ANTENNA ON M-60A-1 TANK

D. V. Campbell
W. Kennebeck
A. Zanella
P. Sexton

Communications/ADP Laboratory

March 1977







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US ARMY ELECTRONICS COMMAND FORT MONMOUTH, NEW JERSEY 07703

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## REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER: 14 ECOM-4482

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle): 6 EXPERIMENTAL INVESTIGATION OF VERY HIGH FREQUENCY SLOT ANTENNA ON M-60A-1 TANK.

5. TYPE OF REPORT & PERIOD COVERED: 9 Final Report. Jul[redacted] — Oc[redacted] 1976,

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s): 10 D. V. Campbell, William Kennebeck, A. Zanella, [redacted] Paul Sexton

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Communications/ADP Laboratory
DRSEL-NL-RH
Fort Monmouth, N. J. 07703

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 697846.EF.161.28.01

11. CONTROLLING OFFICE NAME AND ADDRESS
Communications/ADP Laboratory
U. S. Army Electronics Command
Fort Monmouth, New Jersey 07703

12. REPORT DATE: 11 Mar[redacted] 1977

13. NUMBER OF PAGES: 14 12 18p.

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report): UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Statement B: Distribution limited to U. S. Government agencies only; Test and Evaluation, March 1977. Other requests for this document must be referred to Commander, U. S. Army Electronics Command, ATTN: DRSEL-NL-RH, Fort Monmouth, N.J. 07703. and Fort Monmouth

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Camouflaged antenna;
Tank antenna;
Slot antenna;
Low profile antenna;
Antenna for armored vehicles

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Experiments were conducted to compare the relative performance of a low profile VHF slot antenna and a standard whip antenna when mounted on an M-60A-1 Tank. The impedance of the slot antenna was matched to 50 ohms by means of a pi-network. Radiation patterns of the slot antenna and of the whip were obtained at 30.9, 49.9, and 73.9 MHz. The slot antenna provided effective communications over hilly terrain up to a distance of 18 km; however, the whip due to its greater electrical efficiency, provided effective communications over a somewhat greater distance.

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# EXPERIMENTAL INVESTIGATION OF VERY HIGH FREQUENCY SLOT ANTENNA ON M-60A-1 TANK

## 1. INTRODUCTION

The high profile of conventional whip antennas and their vulnerability to small arms fire and shell blasts have long been recognized as detrimental features. Tanks and armored vehicles utilizing such antennas are frequently rendered ineffective or are lost in combat due to the destruction of their communications antennas and subsequent inability to maintain contact with friendly elements. To enhance survivability, low profile antennas were investigated, even though it was expected that their electrical performance would not equal that of conventional whip antennas.

Two approaches to low profile antennas exist. In one approach, the vehicle is used primarily as a ground plane or counterpoise, against which a small antenna is excited. In the other approach, the vehicle is induced to act as the antenna by some suitable means of electrical excitation. Regardless of which approach is used, the vehicle will radiate to some degree because of the current produced on its surface by the antenna. Examples of antennas employing the first approach include small loop antennas, multiturn loop antennas, and capacitively- and inductively-loaded monopoles. This report will be concerned mainly with the second approach, in which the metal body of a tank is energized as an antenna by means of a slot structure [1].

## 2. BACKGROUND

In reference [1], two different versions of the slot antenna are discussed. The first version consisted of a large cavity-backed slot installed on the turret of an M-60 Tank. This slot structure, because of its large cavity, increased the silhouette of the turret significantly, and was therefore abandoned. The second version of the slot structure, somewhat smaller in size, consisted of a metal sheet bent to fit the contour of the turret. This antenna was termed the "dual-slot-structure."

The third version of the slot antenna, to be discussed here, was developed specifically to fit the turret of the M-60A-1 Tank. Except for its contour, it is similar to the second slot antenna discussed in reference [1].

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[1] Kurt Ikrath, Paul Sexton, William Kennebeck, & Peter Pingitore, "VHF slot antennas on tanks," Res. & Dev. Technical Report ECOM-4367, U. S. Army Electronics Command, Fort Monmouth, N. J., November 1975 (AD B007-878).

## 3. THIRD VERSION OF SLOT ANTENNA ON M-60A-1 TANK

This slot structure, also devised to excite the M-60A-1 Tank as an antenna, consists of a metal sheet bent to fit the contour of the back of the turret (see Figs. 1 through 3). The metal sheet was mounted on insulators and spaced a small distance from the turret. The lower-right and -left corners of the metal sheet were connected electrically with the turret by means of the mounting posts normally used to support the bustle rack; the bustle rack was installed on the outer surface of the slot structure. The slot structure is shown schematically in Fig. 4. The generator, which is located at the feedpoint, is connected between the turret and the metal sheet, as shown in the figure.

### 3.1. Impedance Characteristic

The impedance characteristic of the first two versions of the slot antenna is discussed in detail in reference [1]. The discussion considers the effect of various grounding point locations along the metal sheet on the feedpoint impedance.


Fig. 1. Overall view of M-60A-1 Tank with slot antenna.

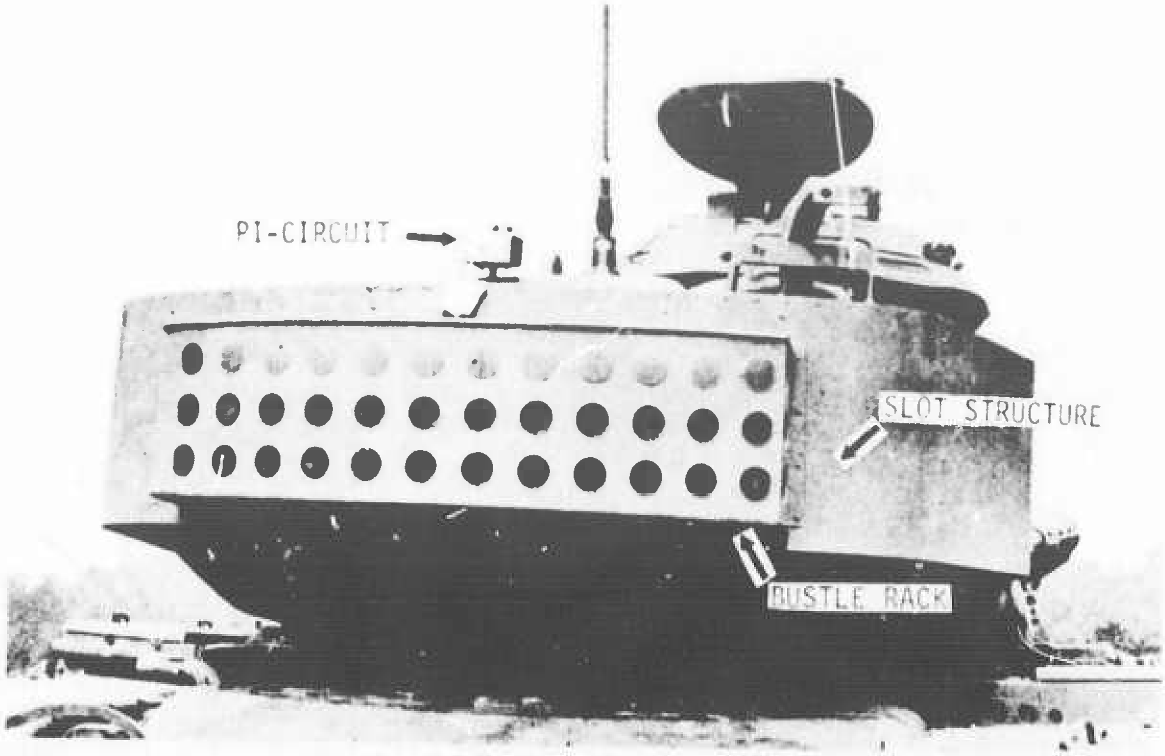


Fig. 2. Close-up view of slot structure on M-60A-1 Tank.

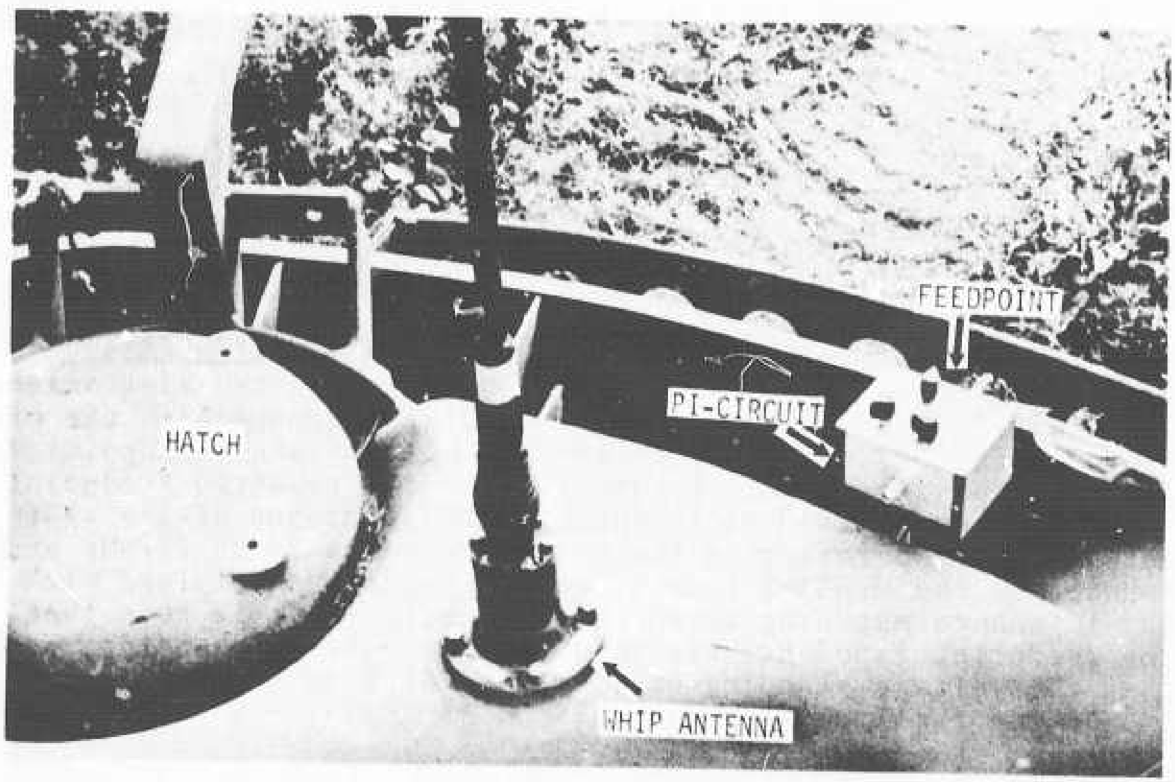


Fig. 3. Top view showing pi-circuit and portion of slot antenna on M-60A-1 Tank.

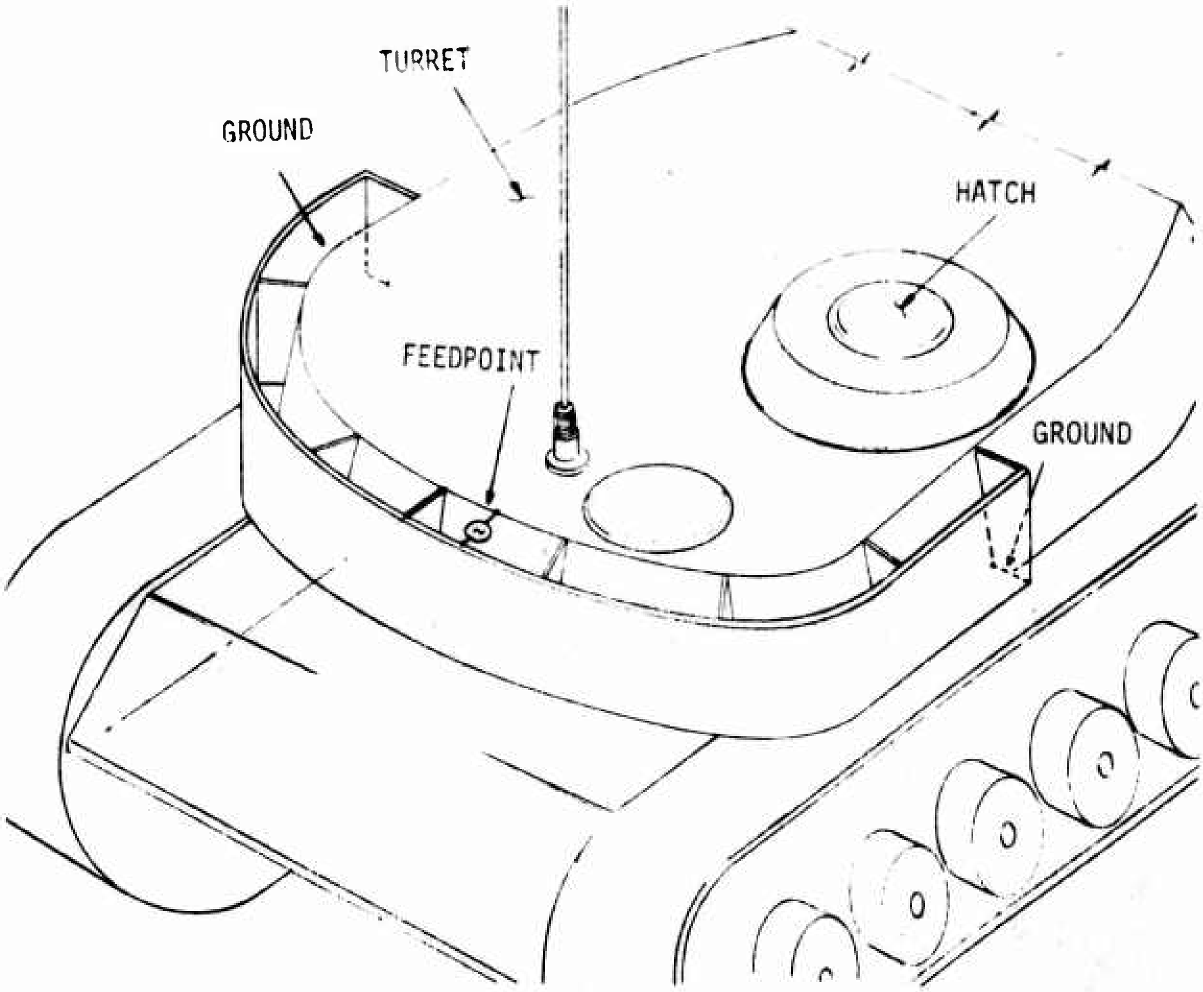


Fig. 4. Schematic of slot antenna on M-60A-1 Tank.

3.1.1. Impedance characteristic of third version without matching circuit. The third version of the slot antenna, which was fed near the top center point and grounded in the manner shown in Fig. 4, offered a reasonably well-behaved feedpoint impedance characteristic. Figure 5 shows the measured feedpoint impedance (normalized to 50 ohms) of this version of the slot antenna when operating in the frequency range 28 to 75 MHz and mounted on the M-60A-1 Tank. The impedance was obtained with the impedance matching network disconnected. It is seen that the feedpoint impedance was inductive at most frequencies, and that the voltage standing-wave ratio (VSWR) exceeded three, except for the frequency range 53 to 55 MHz.

IMPEDANCE OR ADMITTANCE COORDINATES

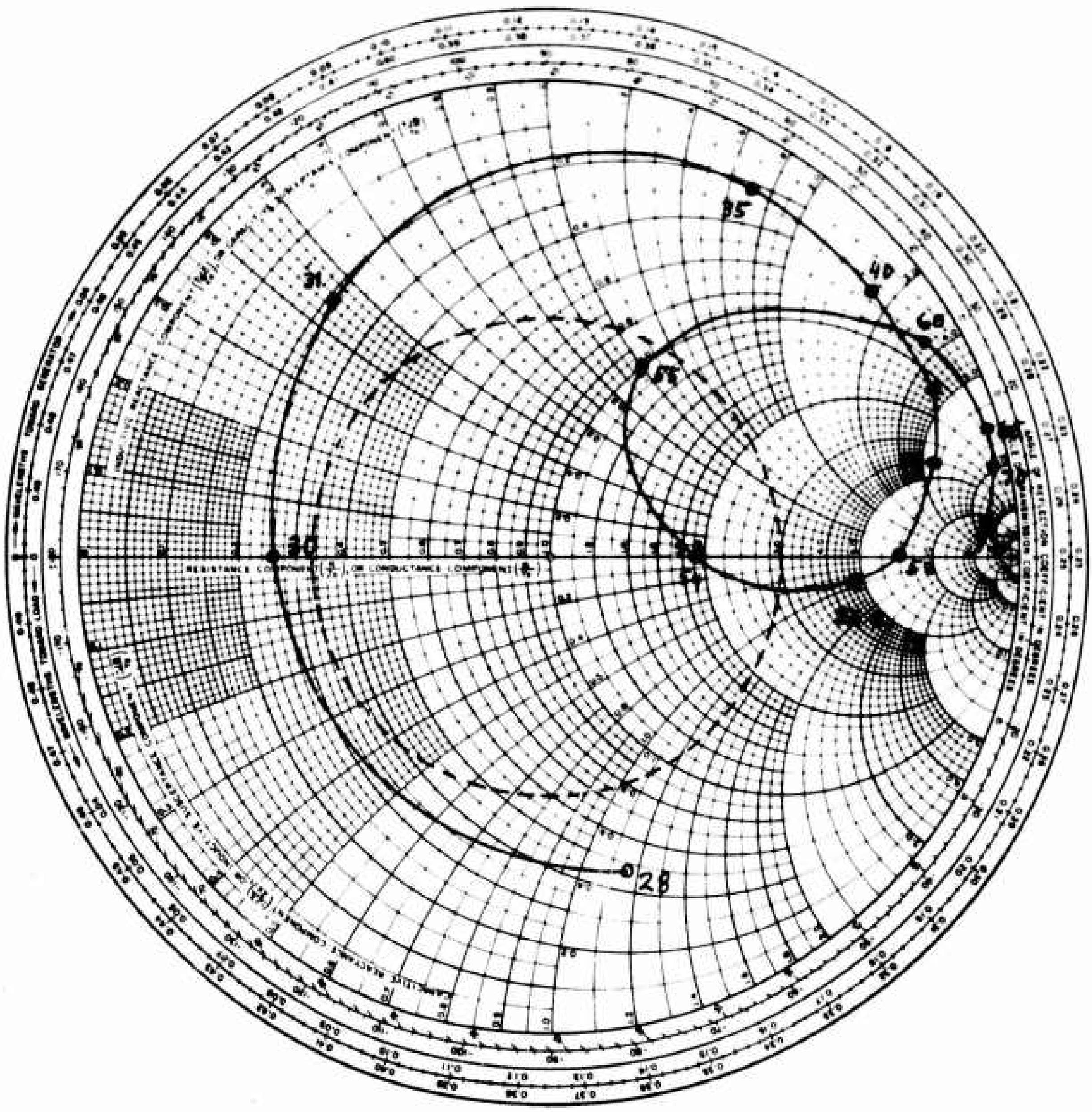


Fig. 5. Measured feedpoint impedance (normalized to 50 ohms) of slot antenna on M-60A-1 Tank.

3.1.2. Impedance characteristic of third version with matching circuit. The 50-ohm transmission line was matched to the feedpoint impedance of the slot structure by means of an adjustable pi-circuit installed next to the feedpoint. This circuit (Fig. 6) was used to transform the feedpoint impedance to 50 ohms. By manual adjustment of the reactances of the pi-circuit, it was possible to obtain a VSWR of $< 1.5$ over the frequency range 30 to 76 MHz.

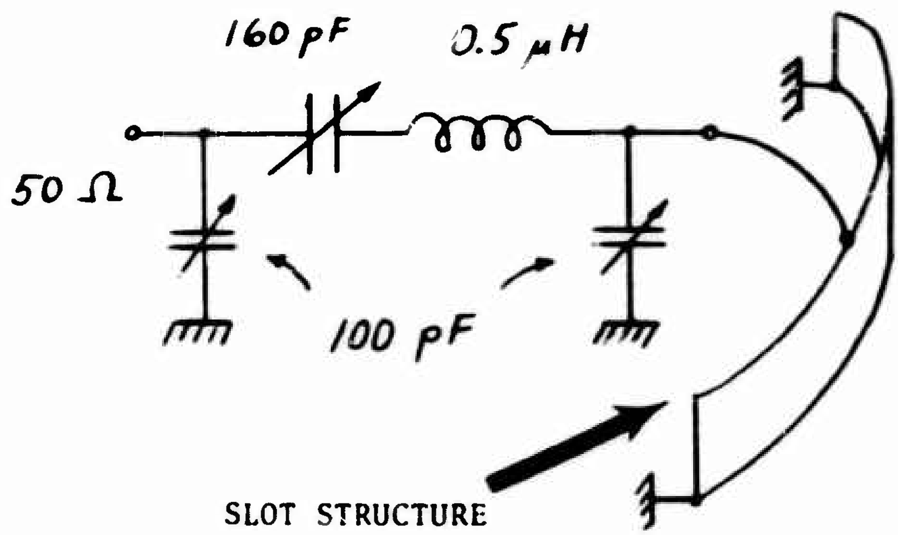


Fig. 6. Schematic diagram of pi-circuit and slot structure.

## 3.2. Voice Communications Range

Tests to determine the communications range obtainable between the M-60A-1 Tank and a small truck, both of which were equipped with standard vehicular radios, type AN/VRC-12, were performed at Aberdeen Proving Ground, Maryland. To facilitate correlation with the radiation patterns, the truck was driven away from the tank in the direction of the gun in its tied down position. The M-60A-1 Tank remained stationary.

Results obtained with the standard AS-1729 Whip Antenna and with the slot antenna at a frequency of 49.9 MHz were compared. A radiated power of 37 watts was used with both antennas. The slot antenna provided a strong signal at a distance of 18 km; the whip antenna provided a strong signal at 19 km. At 19 km, the slot antenna provided a weak signal. The whip antenna provided useable communications at 30 km, but the signal was weak.

### 3.3. Radiation Patterns

The radiation patterns of the slot antenna and of the standard whip antenna AS-1729 mounted in turn on the M-60A-1 Tank were measured at 30.9, 49.9, and 73.9 MHz. These measurements were made by driving the tank in a circle and recording the vertically-polarized received field strength at a point 820 meters away from the center of the circle. The recordings were later converted to polar form to facilitate interpretation. Patterns were obtained with the gun in its tied down position (Figs. 7 through 9) and also with the gun elevated and pointing in the opposite direction (Figs. 10 through 12). The orientation of the tank is indicated in each pattern. To facilitate comparison of the relative effectiveness of the two antennas, these patterns were normalized to the same input power. Thus, from these patterns, the difference in the signal strength between the two antennas can be obtained in dB units for any direction.

Examination of the patterns shows that the radiation provided by the whip antenna was essentially omnidirectional for all the frequencies measured. The slot patterns were reasonably circular at 30.9 and 49.9 MHz, but at 73.9 MHz the pattern was very distorted. It is interesting to compare the 73.9 MHz patterns of the slot antenna when the gun was tied down (Fig. 9) with the patterns obtained when the gun was raised and aimed forward (Fig. 12). It is seen that the 73.9 MHz radiation pattern was somewhat improved when the gun was raised and aimed forward, indicating that the tank radiated rather strongly as an antenna at the higher frequencies in the VHF band. At lower VHF frequencies, results with the slot antenna compared favorably with those for the whip antenna, the average field intensity being approximately 6 dB less than that achieved with the whip.

## 4. CONCLUSIONS

### 4.1. Patterns, Efficiency, Range, and Impedance

The third version of the slot antenna mounted on the M-60A-1 Tank was found to provide good radiation patterns in the lower portion of the VHF band; it was, however, somewhat less efficient than the standard whip antenna. The communications range provided by the slot antenna has not been determined at all frequencies in the VHF band; however, at midband, the slot antenna on the tank provided adequate communications at a distance of 18 km. The impedance of the slot antenna could be matched to 50-ohm radios.

### 4.2. Operational Considerations

The slot antenna reduced the height signature of the tank, but increased the profile of the turret. In addition, the slot structure may trap projectiles and thus decrease, rather than increase, the survivability of a tank. Since the separation

30.9 MHz

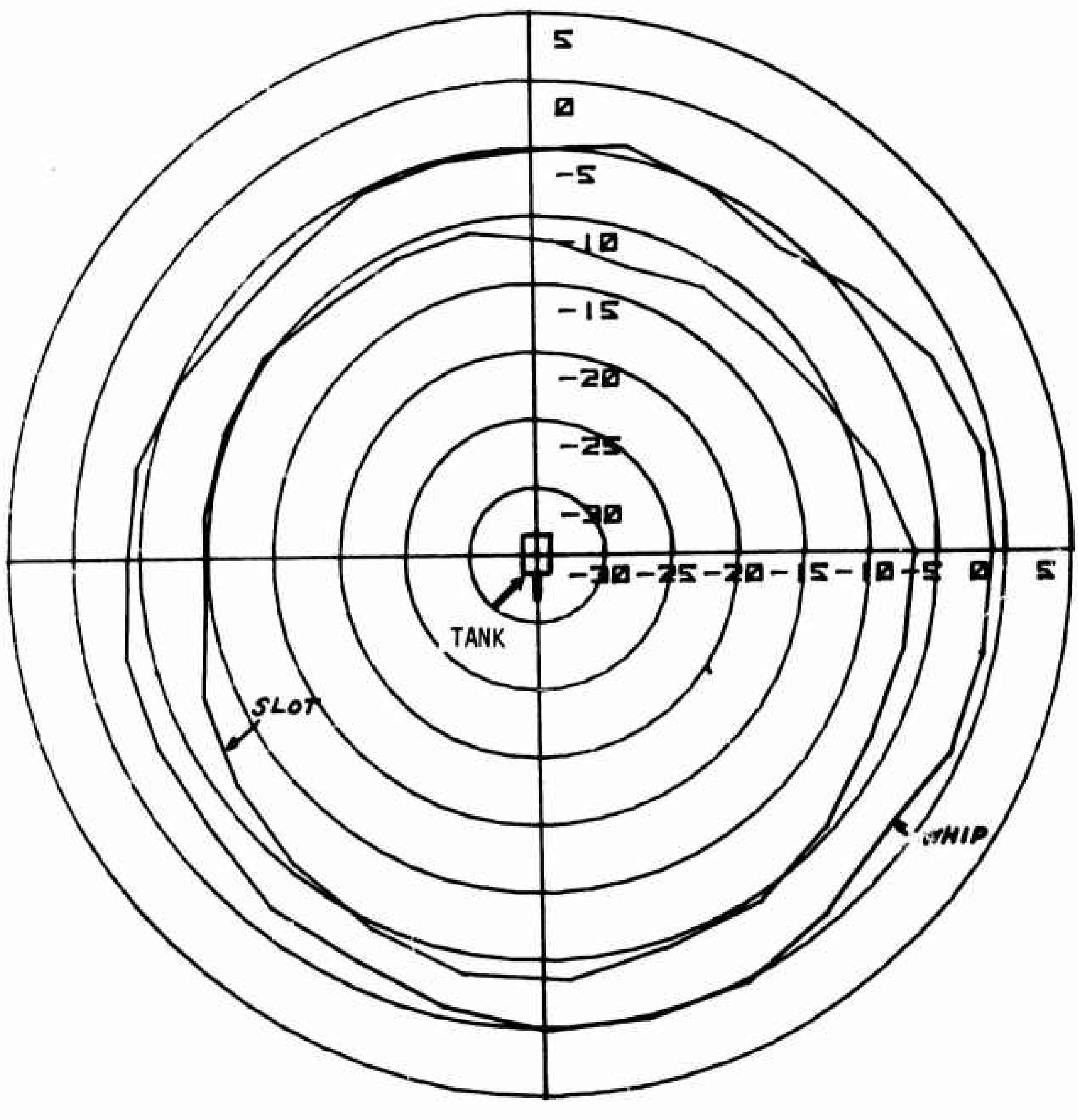


Fig. 7. Measured radiation pattern at 30.9 MHz of slot antenna and of whip antenna on M-60A-1 Tank (gun tied down). Field intensity given in dB.

49.9 MHz

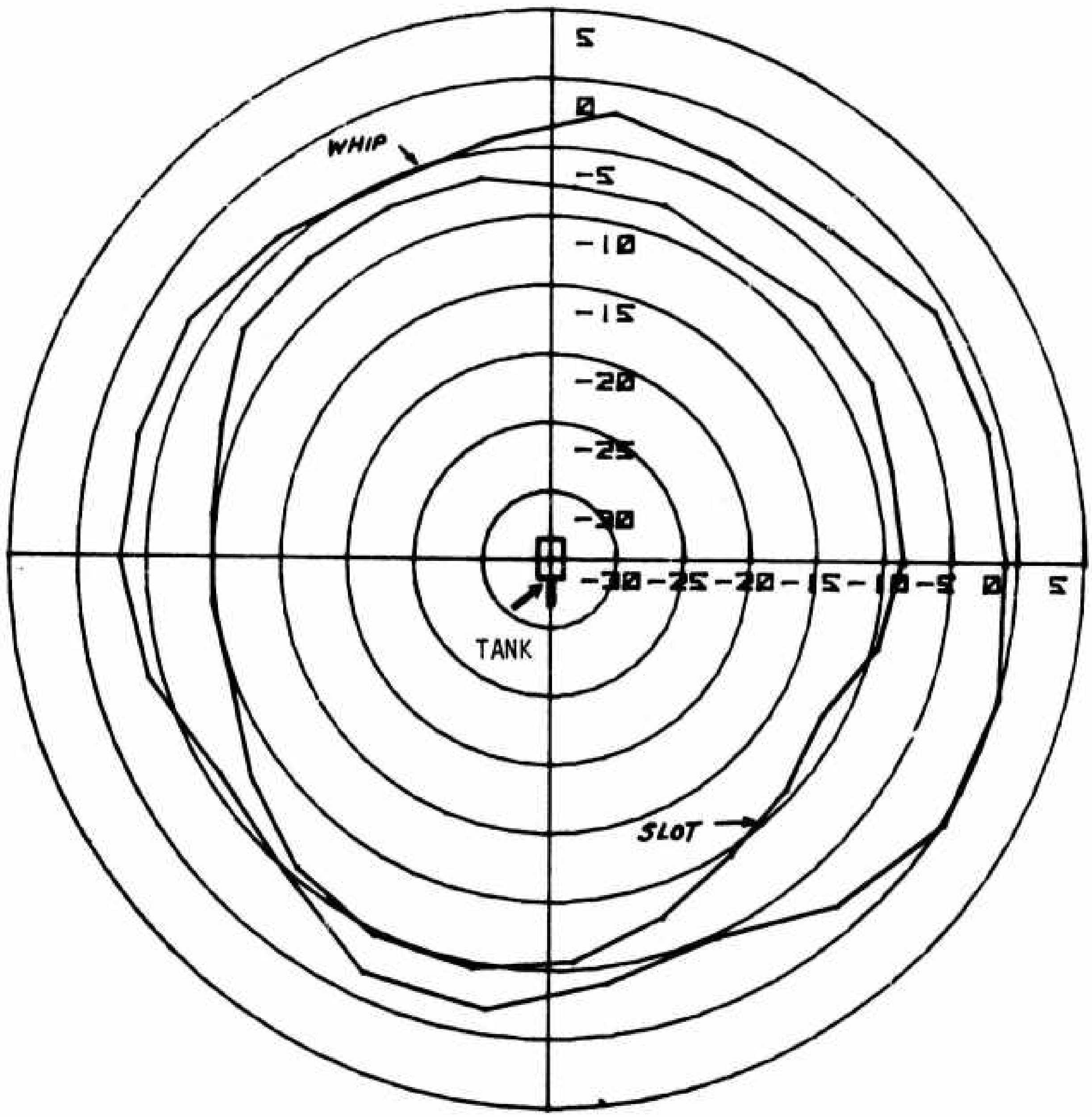


Fig. 8. Measured radiation pattern at 49.9 MHz of slot antenna and of whip antenna on M-60A-1 Tank (gun tied down). Field intensity given in dB.

**73.9 MHz**

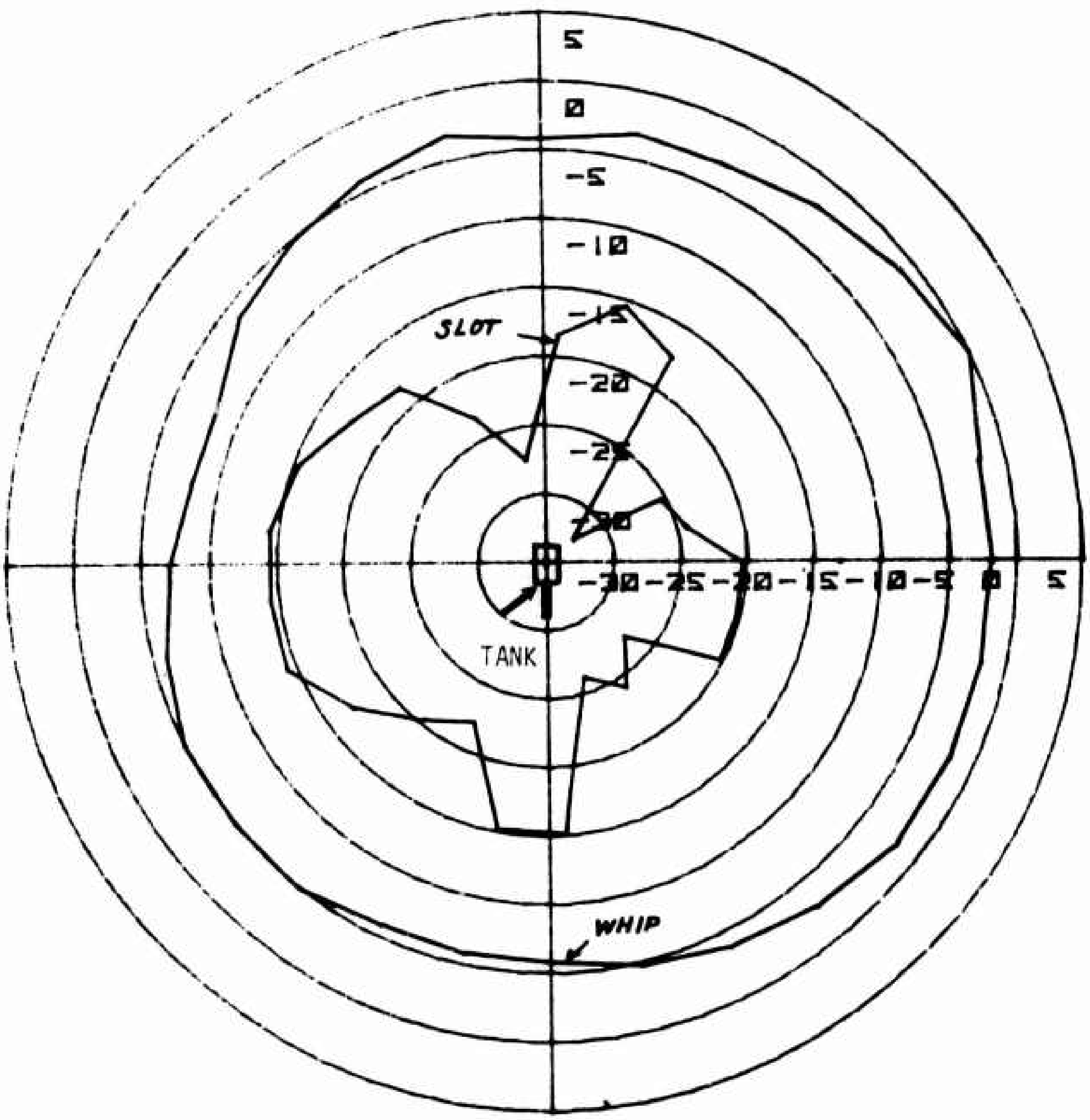


Fig. 9. Measured radiation pattern at 73.9 MHz of slot antenna and of whip antenna on M-60A-1 Tank (gun tied down). Field intensity given in dB.

30.9 MHz
GUN RAISED

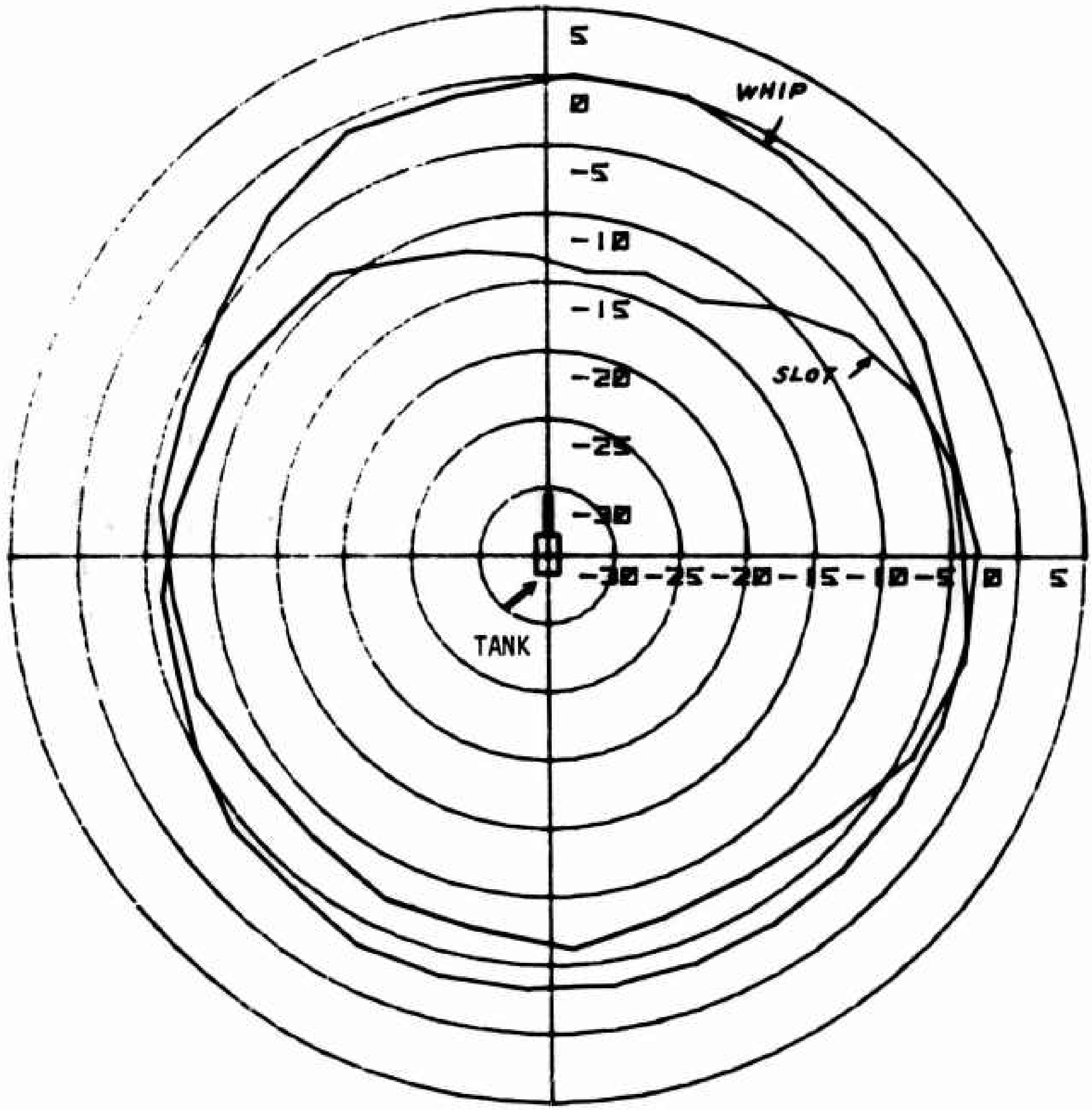


Fig. 10. Measured radiation pattern at 30.9 MHz of slot antenna and of whip antenna on M-60A-1 Tank (gun elevated and aimed in direction of driver). Field intensity given in dB.

**49.9 MHz**
**GUN RAISED**

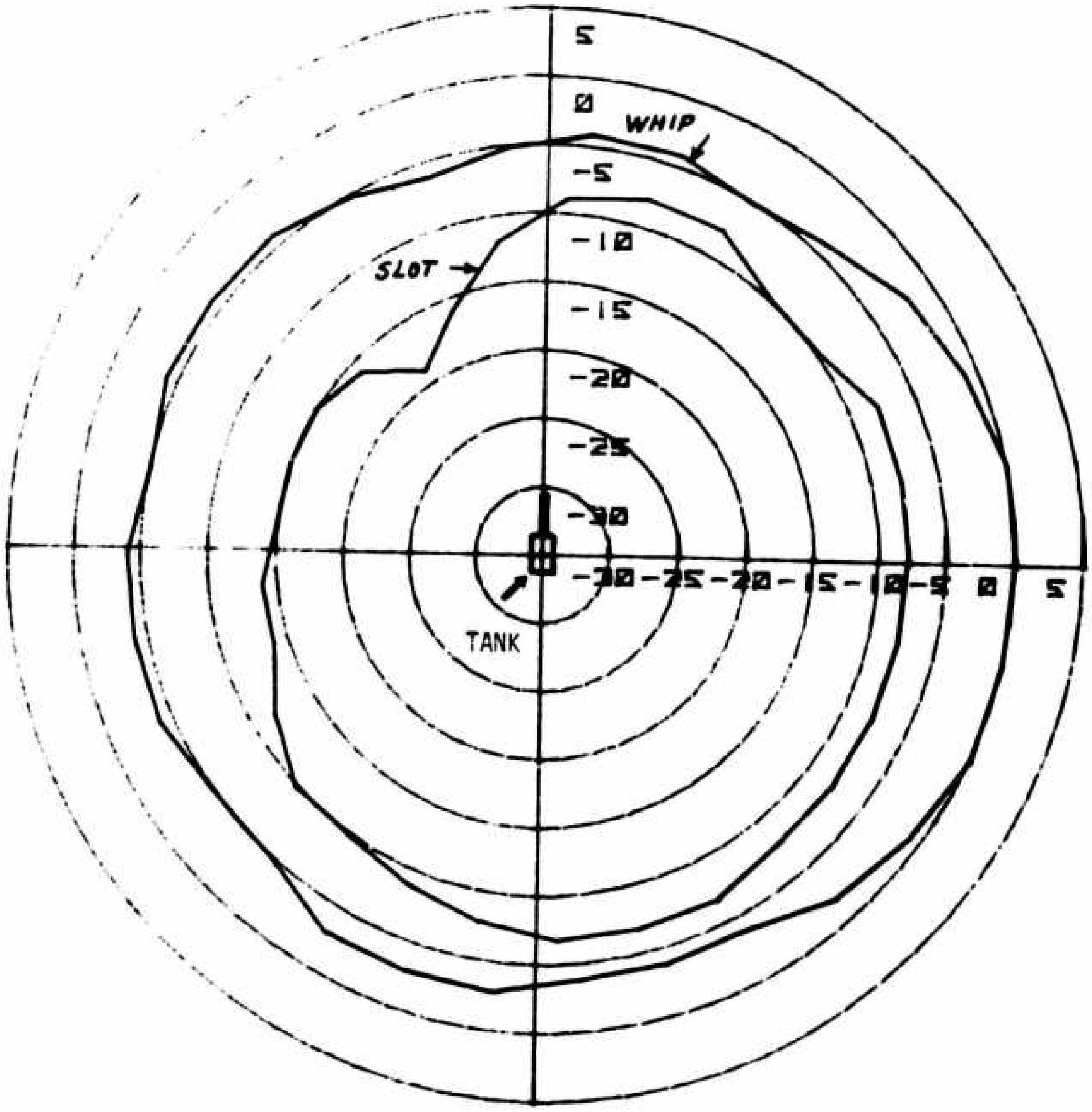


Fig. 11. Measured radiation pattern at 49.9 MHz of slot antenna and of whip antenna on M-60A-1 Tank (gun elevated and aimed in direction of driver). Field intensity given in dB.

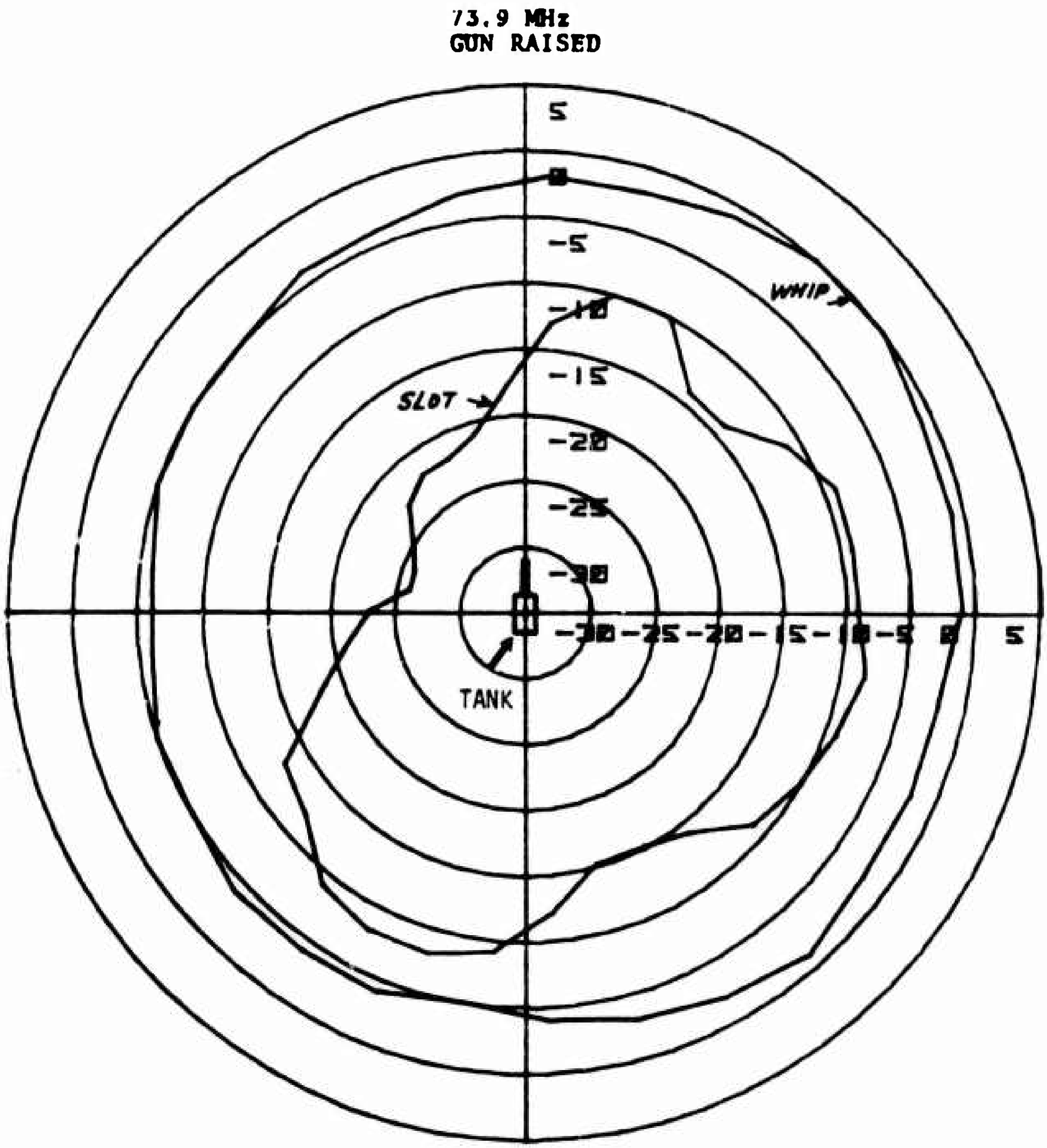


Fig. 12. Measured radiation pattern at 73.9 MHz of slot antenna and of whip antenna on M-60A-1 Tank (gun elevated and aimed in direction of driver). Field intensity given in dB.

between tanks in combat usually does not exceed 2 to 4 km, the communications range achieved with the slot antenna should be adequate for tactical missions.

## 5. RECOMMENDATIONS

This study suggests that slot antennas compare favorably with standard whip antennas and that they provide adequate communications within the operating range normally used during combat. The performance of the experimental slot antenna should be compared with the performance of other low profile antennas (e.g., small loop antennas and small top-loaded antennas) either currently available or under development.

Slot antennas of smaller size should be investigated. In addition, practical tuning systems which do not require manual adjustment should be considered. Techniques for controlling radiation patterns of the slot antenna should also be explored. For example, alternative feed systems such as those explained in [1] as well as different mounting locations for the slot structure should be studied. (In this connection, it is likely that the radiation pattern of any electrically small antenna will be somewhat distorted by the vehicle.) The possibility of projectile trapping must be considered if the tank profile is modified by the addition of an antenna. Regardless of the antenna ultimately used, it must be blast resistant.

## ACKNOWLEDGMENTS

Support for this work was provided by MERADCOM, Fort Belvoir, Virginia; helpful suggestions were provided by Messrs. Dallas Barr and Thomas Steck and by Major William Emerson of that activity. Mr. Gottfried Vogt, Electronic Warfare Laboratory, ECOM, provided valuable technical advice. Closely involved in the early stages of the investigation were Messrs. Peter Pingitore and Enrico Ivone, also of EW Laboratory. Mr. Charles M. DeSantis, ECOM, developed the computer program for converting the recorded radiation patterns from rectangular form into polar form.